

# Nuclear Science Program at Texas A&M University

## Status report prepared for NSAC Meeting - 29, 30 January, 2001

**Funding: (DOE)      FY2000: \$ 2,536,000                      FY2001: \$ 2,514,000**

|                  |                          |                          |                        |                          |                                |
|------------------|--------------------------|--------------------------|------------------------|--------------------------|--------------------------------|
| <b>Staffing:</b> | <u><b>Perm Ph.D.</b></u> | <u><b>Tech/Admin</b></u> | <u><b>Postdoc.</b></u> | <u><b>Grad.Stdt.</b></u> | <u><b>Undergrad. Stdt.</b></u> |
| <b>FY2000:</b>   | 21                       | 29                       | 10                     | 19                       | 11                             |

|                |                |                        |                                 |
|----------------|----------------|------------------------|---------------------------------|
| <b>Users:</b>  | <b>Total #</b> | <b>Ph.D./G.S/Other</b> | <b>DOE/NSF/Other US/Foreign</b> |
| <b>FY2000:</b> | 52**           | 78% : 20% : 2%         | 12% : 2% : 0% : 86%             |

**\*\* *Fundamental research users and collaborators in addition to TAMU personnel. For radiation line applications add approximately 70 personnel ~ 57% industrial ,43% NASA.***

### **I. Introduction**

The Cyclotron Institute of Texas A&M University is jointly supported by the U.S. Department of Energy and the State of Texas. Institute staff carry out a broad program of original research encompassing light ion and heavy ion studies in nuclear structure, nuclear astrophysics, fundamental interactions, nuclear dynamics and nuclear thermodynamics and atomic physics. This work is reported in ~ 50 papers per year in scientific journals. The Institute's K500 superconducting cyclotron is operated full time ( 24/7 ) in support of this research and of accelerator beam applications. Other scientists from the U.S. and from many other countries use the Institute facilities and collaborate in the Institute research programs.

### **II. Major Research Programs** ( Project leaders are indicated in parentheses )

**Nuclear Structure-**The Institute is a recognized leader in research on the incompressibility of the nucleus through studies of the Giant Monopole and Isoscalar Giant Dipole Resonances in medium and heavy nuclei. Recently two ISGDR components have been identified in  $^{90}\text{Zr}$ ,  $^{116}\text{Sn}$ , and  $^{208}\text{Pb}$ , one at  $E_x \sim 114 \text{ MeV/A}^{1/3}$  which is a compression mode whose energy is dependent on nuclear matter compressibility and a new toroidal surface mode at  $E_x \sim 70/A^{1/3} \text{ MeV}$ . The next emphasis will be on systematic experimental and theoretical investigations of resonances in isotope chains such as  $^{112}\text{Sn}$ - $^{124}\text{Sn}$  to study the dependence on neutron number and to look for weak components of these resonances that might significantly shift their centroids and affect nuclear matter incompressibility determinations. ( D. Youngblood et al)

**Nuclear Astrophysics-**The Institute has developed an innovative new technique, asymptotic normalization coefficient measurements, for nuclear astrophysics. This technique has been identified as an important tool for investigating direct radiative capture rates at astrophysical energies. The technique has already been applied to determine the  $^7\text{Be}(p, \gamma)^8\text{B}$  reaction rate, which plays a central role in the solar neutrino question and is being used for other important reactions, e.g.,  $^{11}\text{C}(p, \gamma)^{12}\text{N}$  and  $^8\text{B}(p, \gamma)^9\text{C}$ . Detector options that will allow extension of the measurement of ANC's to heavier systems are being explored. ( C. Gagliardi, R. Tribble et al)

**Fundamental Symmetries-** Institute scientists are carrying out an important program of high sensitivity measurements of superallowed  $0^+ \rightarrow 0^+ \beta$ -decay transitions. These measurements provide a crucial test of both the constancy of the weak vector coupling constant and of the Standard Model's definitive predictions for quark mixing. Measurements of branching ratios and half-lives for  $^{22}\text{Mg}$ ,  $^{34}\text{Ar}$  and  $^{30}\text{S}$ , combined with mass determinations to be performed with the

Canadian Penning Trap at Argonne, will allow determinations of precise  $F_t$ -values for all three superallowed transitions. The results will be used to test the charge-dependent corrections that must be applied to all precision superallowed measurements before they can be used to determine  $G_V$ , and ultimately to test the unitarity of the CKM matrix. ( J. Hardy et al)

**Nuclear Dynamics and Thermodynamics**-The Institute program in heavy ion reaction dynamics and thermodynamics investigates the properties and the decay modes of nuclear Systems from low energy up to the limits of thermal and rotational stability, testing theories of many body systems, chaotic regime dynamics and the statistical mechanics of strongly interacting, finite quantum systems. Systematic measurements in intermediate energy heavy ion collisions are establishing the degree of thermal, chemical and isospin equilibration, the mechanism of nuclear disassembly, the caloric curve and the mass and isospin dependence of limiting temperatures. ( J. Natowitz, S. Yennello , R. Schmitt et al )

**Nuclear Theory** – The theory program at the Institute encompasses many fundamental questions, many of which are strongly related to those addressed in the experimental programs. Subjects of particular emphasis are relativistic collisions and the properties of hadrons in hot dense matter (C-M. Ko et al ), the nuclear response function and correlations in nuclei ( S. Shlomo et al ) and nuclear astrophysics and few body problems ( A. Mukhamedzhanov et al). In addition a group of very talented theorists regularly spend extended periods at the Institute as collaborators in the theory programs.

**External Programs** – In addition to pursuing the internal programs that employ the K500 Superconducting Cyclotron, Institute scientists presently collaborate in three major experimental efforts at other accelerator facilities. These are:

BRAHMS at RHIC –BRAHMS is a two arm forward and mid-rapidity spectrometer designed to measure high quality inclusive momentum spectra of identified charged hadrons over a wide range in rapidity and transverse momentum in . It is ideally suited to study stopping and the centrality dependence of the net baryon distribution. The TAMU group built the two Zero Degree Calorimeters for BRAHMS and is also pursuing the understanding of electromagnetic excitation processes at RHIC energies. ( M. Murray, K. Hagel et al )

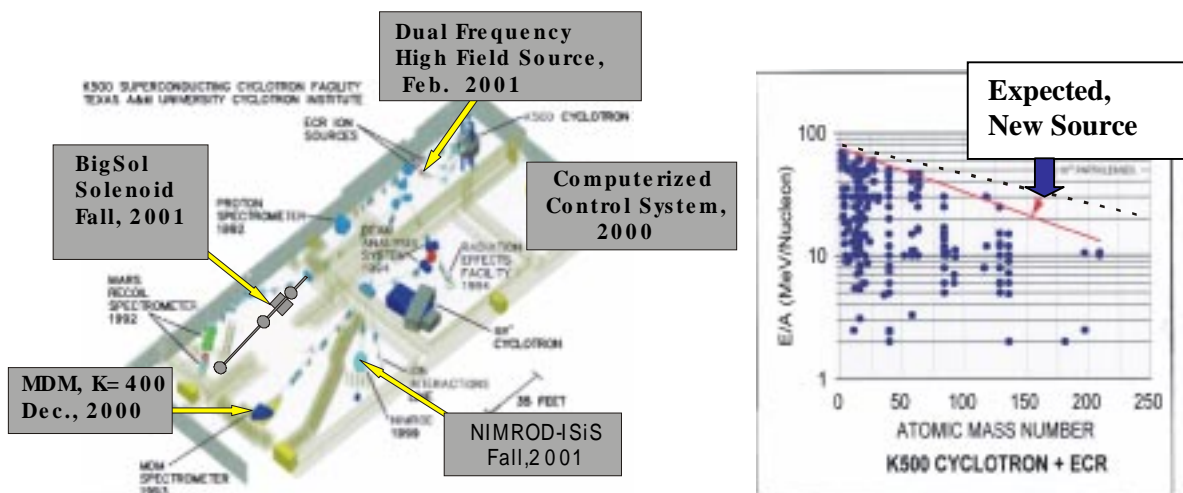
TWIST at TRIUMF – At TRIUMF Institute scientists comprise one of the lead groups in a new experiment to measure the Michel parameters in normal muon decay. The Standard Model provides definite predictions for each of the Michel parameters, based on its assumption that the weak interaction is purely left-handed. Any deviation between the measured values and the predictions would require the introduction of right-handed weak currents or other new physics outside the current Standard Model. ( C. Gagliardi, R. Tribble et al )

Spin Physics at RHIC - Carl Gagliardi and Bob Tribble have now joined the STAR collaboration and will work on the development of the Electromagnetic Calorimeter end-cap for the spin physics program with STAR.

In addition Institute scientists perform experiments as users or collaborators at other complementary facilities ( Argonne, TRIUMF, Legnaro, Dubna etc. ) as appropriate to the program. Approximately 20 % of the total Institute scientific effort is in external mode and this is expected to remain relatively constant.

### III. Accelerator Facilities and Equipment

The Institute programs are centered about the locally constructed K500 Super-conducting Cyclotron which has two high performance ECR sources. A new dual-frequency high-field ECR source is just being completed. The figure below presents a schematic view of the layout of the accelerator and associated experimental equipment and indicates facility developments underway or recently completed. The present beam capabilities of the accelerator and the expanded capabilities expected with the new source are also indicated. The capabilities of the accelerator system are ideally suited to the experimental program being pursued.



### **Major Equipment**

**Multipole-Dipole-Multipole (MDM) Spectrometer** - Charged particles, having energies up to 100A MeV are measured with high resolution ( $1/4000$ ) over a broad energy range ( $E_{\text{max}}/E_{\text{min}} = 1.52$ ) with a solid-angle up to 8 msr. The focal plane detector measures  $x$  and  $y$  position, energy and time-of-flight, enabling ray tracing and unit mass identification up to  $A = 40$ .

**Momentum Achromat Recoil Spectrometer (MARS)** – a recoil separator with large solid angle (9msr) and energy ( $\pm 9\%$ ) acceptance and mass resolution of  $1/300$ . The exceptionally good beam rejection factor ( $>10^{15}$ ) resulting from its unique two dispersive planes design makes it well suited for inverse kinematics separation of exotic nuclei and production of secondary rare beams.

**Proton Spectrometer (PSP)** - The proton spectrometer is a large solid-angle, moderate resolution, magnetic spectrograph that is optimized for detection of multiple correlated particles produced in nuclear reactions.

**4-pi Charged Particle, 4-pi Neutron Detection System (NIMROD)** - This system provides high efficiency detection and identification of charged particles and neutrons. This includes isotopic identification to at least  $Z=10$ . With the addition of one half of the Indiana ISiS detector (in progress) it consists of a cylindrical array of 156 detector telescopes between 3 and 170 degrees inside a large volume, segmented, liquid scintillation detector.

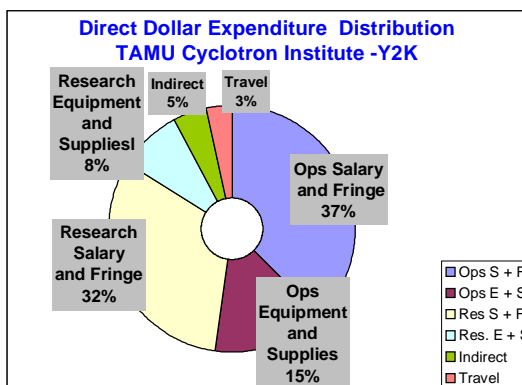
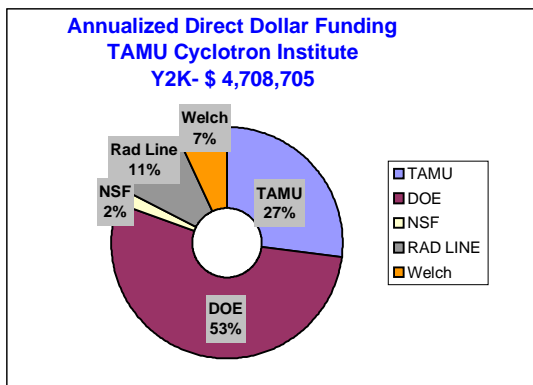
**Radiation Effects Line** - Designed for advanced radiation testing of Very Large Scale Integrated (VLSI) circuits, this facility features a large-volume target chamber with a versatile target positioning assembly, and a variety of industry standard vacuum feed-through connectors. A large

selection of high-energy beams covering a broad range of LET has been developed specifically for this purpose. These beams have a high degree of uniformity over a large area.

Included in other equipment currently available to the program are two forward angle particle arrays-the Laval University HERACLES CsI detector system and FAUST a Si-CsI array, the ORNL-TAMU-NSCL National Barium Fluoride gamma array, high resolution Ge detectors and a tape transport system.

#### **IV. Operational Issues**

**Budget-** The facility is very cost effective. The charts below indicate the distribution of total Institute support. Federal funds account for 53% of direct dollars to the Institute. Of this amount 54% is required to support the facility operation leaving 46% for research activities. Note that these charts are not pie charts but doughnut charts-because there is always a significant hole, now ~\$ 600,000. While we have been able to build the radiation line usage to the point where it now provides 11% of our total funding, inflation is taking its toll and maintaining a truly competitive facility will necessarily require development funds and some operating fund increases.



**Students** - We currently have 19 graduate students. Many are very good but the total is 5-10 fewer than optimum. We are able to support them but TAMU stipends are low and should be increased. We also typically have ~10 very bright undergraduates involved in our program.

#### **V. Future Development of the Facility**

Over the past two years Cyclotron Institute faculty and staff members have devoted considerable thought to potential upgrades which would enhance our capabilities as a versatile stable beam facility with moderate rare beam capacity. We are currently exploring the enhanced rare beam possibilities that could be offered by superconducting solenoids both in fragmentation beam production and IGISOL operations. Longer term we believe that we could accomplish a very significant upgrade of this facility by re-activating our 88" cyclotron for use as a driver for production of rare isotopes for acceleration in the K500 Cyclotron. High quality accelerated rare beams of both neutron deficient and neutron rich isotopes could be provided in the 5 to 50 MeV/u range. The expanded range of stable and rare beams would create an exceptionally versatile facility for low and intermediate energy research. In addition to greatly extending the reach of the present TAMU research program, this facility could play a much wider role in support of the national research effort. Such an upgrade is well within our technical capabilities and could be realized within two years of being funded. A very *preliminary* cost estimate is \$5,000,000 with ~20% coming from TAMU.